

**We Claim:**

sub B1) 1. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system, comprising:

- a first plate;
- a second plate disposed adjacent the first plate;
- a first plurality of load cells, each of the first plurality of load cells configured to detect a force applied to the first plate along at least one axis and output a signal representative of the detected force;
- a second plurality of load cells, each of the second plurality of load cells configured to detect a force applied to the second plate along at least one axis and output a signal representative of the detected force; and
- a processor adapted to execute at least one force analysis instruction set,

whereby the force analysis instruction set receives the signals output from the first and second plurality of load cells and calculates, in combination with the processor, a magnitude and location of a force applied to either of the first plate and the second plate.

2. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 1,

whereby the force analysis instruction set receives the signals output from the first and second plurality of load cells and calculates, in combination with the processor, a magnitude and location of a force applied to both the first plate and the second plate.



7. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 3, wherein the first plate and the second plate are disposed within a floor so that the surface of the first plate and the second plate are substantially level with a surface of the floor.

8. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 3, further comprising:

a step-up disposed at a proximal side of the first plate and the second plate;

a ramp down disposed at a distal side of first plate and the second plate.

9. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 8, further comprising:

a railing disposed on each side of the step-up, the first plate, the second plate, and the ramp down;

a divider disposed between the first plate and the second plate.

10. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 9, further comprising:

a speed sensor to determine a speed of the animal passing through the diagnostic system, wherein the speed sensor is at least one of an optically-based and acoustic-based sensor.



compute a total force applied to at least one of the first plate and second plate by summing the magnitudes of forces applied to a respective one of the first and second plates.

9/ 15. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 14, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a weight of the animal passing through the system by summing the magnitudes of forces applied to the first plate and the second plate.

10/ 16. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 15, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a position of the force applied to at least one of the first plate and the second plate.

11/ 17. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 16, wherein the force analysis instruction set comprises instructions for determining a position of the force along at least one of an X-axis, Y-axis, and Z-axis by summing moments and forces along respective axes to solve  $n$  equations in  $n$  unknowns, where  $n$  is an integer.

12/ 18. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 17, wherein

the force analysis instruction set comprises instructions which, when executed by the processor, compute an understep value for at least one side of the animal by calculating a difference between a position at which a fore limb applies a force to one of the first and second plates and a position at which a hind limb on the same side of the animal applies a force to the same plate.

17/ 19. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 11, wherein position of the force applied to at least one of the first plate and the second plate is computed as a function of time.

18/ 20. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 17, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a peak normalized ground reaction force variable for at least one of the first plate and second plate by dividing the force applied to a respective one of the first plate and second plate by the weight of the animal.

19/ 21. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 18, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a first peak normalized ground reaction force variable for the animal's fore limbs and a second peak normalized ground reaction force variable for the animal's hind limbs by dividing

the force applied to a respective one of the animal's fore limbs and hind limbs by the weight of the animal.

21/ 22. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim <sup>18</sup>20, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute an impulse variable for each force applied to the first plate or the second plate by integrating the normalized ground reaction force value with respect to the duration of application of each force to a respective plate.

20/ 23. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim <sup>19</sup>21, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a first impulse variable for a force applied to the first plate or the second plate by the animal's fore limbs and a second impulse variable for a force applied the first plate or the second plate by the animal's hind limbs, wherein each of the first and second impulse variable is calculated by integrating the normalized ground reaction force value with respect to the duration of application of each force to a respective plate and a second impulse variable for a force applied.

22/ 24. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim <sup>21</sup>22, wherein the force analysis instruction set comprises instructions which, when executed by the processor,

compute a stance time variable by calculating a total time that a limb is in contact with the first plate or second plate.

28/ 25. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 21, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a first stance time variable for a fore limb and a second stance time variable for a rear limb by calculating a total time that a limb is in contact with the first plate or second plate.

23/ 26. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 22, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the total time that a limb is in contact with the first plate or second plate by calculating a difference between a first time at which an applied force exceeds a predetermined threshold force and a second time at which an applied force falls below the predetermined threshold force for a discrete force application event, and

wherein the predetermined threshold force is between 0.0 and 5.0 lbf.

29/ 27. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 28, wherein the force analysis instruction set comprises instructions which, when executed by the processor,



compute a first total time that a fore limb is in contact with the first plate or second plate by calculating a difference between a first time at which an applied force from the fore limb exceeds a predetermined threshold force and a second time at which the applied force from the fore limb falls below the predetermined threshold force thus defining a first discrete force application event; and

compute a second total time that a rear limb is in contact with the first plate or second plate by calculating a difference between a first time at which an applied force from the rear limb exceeds a predetermined threshold force and a second time at which the applied force from the rear limb falls below the predetermined threshold force thus defining a second discrete force application event;

27. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 26, wherein the predetermined threshold force is between 0.0 and 5.0 lbf.

28. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 24, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a normalized average ground reaction force variable by dividing the impulse variable by the stance time variable.

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29. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 25, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a first normalized average ground reaction force variable by dividing the impulse variable for a first applied force by the first stance time variable and compute a second normalized average ground reaction force variable by dividing the impulse variable for a second applied force by the second stance time variable.

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30. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 28, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a speed of the animal using a signal output by the speed sensing device.

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31. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 29, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a speed of the animal using a signal output by the speed sensing device.

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32. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 30, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a step size of the animal by calculating a difference between a first position at which a

limb applies a force to one of the first and second plates and a second position at which the same limb applies a force to the respective first or second plate along an axis of motion of the animal.

33. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 31, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the product of the impulse variable and the animal speed to obtain a characteristic unit length.

34. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 32, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the product of the first impulse variable and the animal speed to obtain a first characteristic unit length and to compute the product of the second impulse variable and the animal speed to obtain a second characteristic unit length.

35. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 18, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the m-energy applied to the first plate or second plate by a limb of the animal by integrating a magnitude of the applied force to the first plate or second plate with respect to a frequency in a frequency domain.

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36. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 18, wherein the force analysis instruction set comprises instructions which, when executed by the processor,

compute a first m-energy applied to one of the first and second plate by a fore limb of the animal by integrating a magnitude of the applied force to the plate with respect to a frequency in a frequency domain, and

compute a second m-energy applied to one of the first and second plate by a hind limb of the animal by integrating a magnitude of the applied force to the plate with respect to a frequency in a frequency domain.

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37. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 18, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the p-energy by taking the product of a magnitude of a force applied to the first plate or second plate by a limb of the animal and frequency integrated over a frequency domain.

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38. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 18, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute a first p-energy by taking the product of a magnitude of a force applied to the first plate or second plate by a fore limb of the animal and frequency integrated over a frequency domain; and



42. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 40, wherein the force analysis instruction set comprises instructions which, when executed by the processor, compute the symmetry factor by taking the dividend of a fore limb movement variable minus a hind limb movement variable on the numerator and a fore limb movement variable plus a hind limb movement variable on the denominator.

43. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable comprise a normalized peak ground reaction force.

44. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable comprise a normalized peak ground reaction force.

45. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise an impulse variable.

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46. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable each comprise an impulse variable.

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47. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise a stance variable.

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48. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable each comprise a stance variable.

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49. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise a normalized average ground reaction force variable.

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50. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein

the fore limb movement variable and the hind limb movement variable each comprise a normalized average ground reaction force variable.

51. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise a step size variable.

52. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable each comprise a step size variable.

53. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise an m-energy variable.

54. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable each comprise an m-energy variable.

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56. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 41, wherein the right limb movement variable and the left limb movement variable each comprise a p-energy variable.

57. A computer-based diagnostic system to detect and analyze ground reaction forces produced by an animal passing through the diagnostic system in accord with claim 42, wherein the fore limb movement variable and the hind limb movement variable each comprise a p-energy variable.

58. A computer-based method for detecting and analyzing ground reaction forces produced by an animal, comprising the steps of:

guiding an animal to move across an instrumented force-sensing floor comprising a left floor plate, a right floor plate, a plurality of left floor plate load cells configured to measure a force applied to the left floor plate and output a force proportioned signal, and a plurality of right floor plate load cells configured to measure a force applied to the right floor plate and output a force proportioned signal;

constraining at least one of the animal's lateral body movement and leg movement so that the animal's left limbs contact the left floor plate and the animal's right limbs contact the right floor plate;

calculating forces applied to the left floor plate and to the right floor plate by summing the signals output by the left floor plate load cells and right floor plate load cells, respectively; and

comparing the calculated forces to a range of forces indicative of at least one of a sound animal condition, an indeterminate animal condition, or a lame animal condition.

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59. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>56</sup>58, further comprising the step of:

computing a weight of the animal passing through the system by summing the magnitudes of forces applied to the first floor plate and the second floor plate.

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60. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>56</sup>58, further comprising the step of:

computing a position of the force applied to at least one of the first floor plate and the second floor plate.

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61. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>56</sup>58, further comprising the step of:

computing a position of the force along at least one of an X-axis, Y-axis, and Z-axis by summing moments and forces along respective axes to solve  $n$  equations in  $n$  unknowns, where  $n$  is an integer.

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62. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>59</sup>61, further comprising the step of:

computing a position of the force applied to at least one of the first floor plate and the second floor plate as a function of time.

61/ 63. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>60/</sup>62, further comprising the step of:

computing a peak normalized ground reaction force variable for at least one of the first floor plate and second floor plate by dividing the force applied to a respective one of the first plate and second plate by the weight of the animal.

62/ 64. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>60/</sup>62, further comprising the step of:

computing an impulse variable for each force applied to the first floor plate or the second floor plate by integrating the normalized ground reaction force value with respect to the duration of application of each force to a respective floor plate.

63/ 65. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>62/</sup>64, further comprising the step of:

computing a stance time variable by calculating a total time that a limb is in contact with the first floor plate or second floor plate.

68/ 66. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>60/</sup>62, further comprising the step of:

computing the total time that a limb is in contact with the first floor plate or second floor plate by calculating a difference between a first time at which an applied force exceeds a





73 75. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>72</sup>74, further comprising the step of:

computing a symmetry factor by taking the dividend of a right limb movement variable minus a left limb movement variable on the numerator and a right limb movement variable plus a left limb movement variable on the denominator.

81 76. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>72</sup>74, further comprising the step of:

computing a symmetry factor by taking the dividend of a fore limb movement variable minus a hind limb movement variable on the numerator and a fore limb movement variable plus a hind limb movement variable on the denominator.

74 77. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable comprise a normalized peak ground reaction force.

82 78. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable comprise a normalized peak ground reaction force.

75 79. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise an impulse variable.

8.3 / 80. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise an impulse variable.

76 / 81. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise a stance variable.

84 / 82. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise a stance variable.

77 / 83. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise a normalized average ground reaction force variable.

85 / 84. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise a normalized average ground reaction force variable.

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78 85. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise a step size variable.

86 86. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise a step size variable.

79 87. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise an m-energy variable.

87 88. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise an m-energy variable.

80 89. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>73</sup>75, wherein the right limb movement variable and the left limb movement variable each comprise a p-energy variable.

88 90. A computer-based method for detecting and analyzing ground reaction forces produced by an animal in accord with claim <sup>81</sup>76, wherein the fore limb movement variable and the hind limb movement variable each comprise a p-energy variable.



91. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal to determine a physical condition of the animal, the instructions, when executed by a computer, causing the computer to carry out the steps of:

calculating ground reaction forces produced by the animal by summing the force proportioned signals output by load cells separately measuring loads of each of a left floor plate and a right floor plate; and

comparing the calculated forces to a range of forces indicative of at least one of a sound animal condition, an indeterminate animal condition, or a lame animal condition.

92. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal in accord with claim 91 to determine a physical condition of the animal, the instructions, when executed by a computer, causing the computer to carry out at least one of the steps of:

computing a weight of the animal passing through the system by summing the magnitudes of forces applied to the first floor plate and the second floor plate;

computing a position of the force applied to at least one of the first floor plate and the second floor plate;

computing a position of the force along at least one of an X-axis, Y-axis, and Z-axis by summing moments and forces along respective axes to solve  $n$  equations in  $n$  unknowns, where  $n$  is an integer;

computing an understep value for at least one side of the animal by calculating a difference between a position at which a fore limb applies a force to one of the first and second plates and a position at which a hind limb on the same side of the animal applies a force to the same plate;

computing a position of the force applied to at least one of the first floor plate and the second floor plate as a function of time;

computing a peak normalized ground reaction force variable for at least one of the first floor plate and second floor plate by dividing the force applied to a respective one of the first plate and second plate by the weight of the animal;

computing an impulse variable for each force applied to the first floor plate or the second floor plate by integrating the normalized ground reaction force value with respect to the duration of application of each force to a respective floor plate;

computing a stance time variable by calculating a total time that a limb is in contact with the first floor plate or second floor plate;

computing the total time that a limb is in contact with the first floor plate or second floor plate by calculating a difference between a first time at which an applied force exceeds a predetermined threshold force and a second time at which an applied force falls below the a predetermined threshold force between about 0.0 and 5.0 lbf for a discrete force application event;

computing a normalized average ground reaction force variable by dividing the impulse variable by the stance time variable;

computing a speed of the animal using a signal output by a speed sensor;

computing the step size of the animal by calculating a difference between a first position at which a limb applies a force to one of the first and second floor plates and a second position at which the same limb applies a force to the respective first or second floor plate along an axis of motion of the animal.

computing a product of the impulse variable and the animal speed to obtain a characteristic unit length;

computing an m-energy applied to the first plate or second plate by a limb of the animal by integrating a magnitude of the applied force to the first floor plate or second floor plate with respect to a frequency in a frequency domain; and

computing a p-energy by taking the product of a magnitude of a force applied to the first floor plate or second floor plate by a limb of the animal and frequency integrated over a frequency domain.

92/93. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal in accord with claim 92 to determine a physical condition of the animal, the instructions, when executed by a computer, causing the computer to carry out the step of:

computing a symmetry factor indicative of a difference in a force applied to the first plate and a force applied to the second plate.

91/94. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal in accord with

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claim 92 to determine a physical condition of the animal, the instructions, when executed by a computer, causing the computer to carry out the step of:

computing a symmetry factor indicative of a difference in a force applied to one of the first plate and the second plate by a fore limb and a force applied to the same one of the first plate and the second plate by a hind limb.

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95. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal in accord with claim 92 to determine a physical condition of the animal, the instructions, when executed by a computer, causing the computer to carry out the step of:

computing a symmetry factor by taking the dividend of a right limb movement variable minus a left limb movement variable on the numerator and a right limb movement variable plus a left limb movement variable on the denominator.

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96. A computer-readable medium bearing instructions enabling a computer having at least one processor to detect and analyze ground reaction forces produced by an animal in accord with claim 93, wherein the right limb movement variable and the left limb movement variable comprise one of a normalized peak ground reaction force, an impulse variable, a stance variable, a normalized average ground reaction force variable, a step size variable, an m-energy variable, and a p-energy variable.